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The benefits and costs of transporting an identity preserved product from Iowa to Taiwan

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The benefits and costs of transporting an identity preserved product from Iowa to Taiwan

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I. INTRODUCTION

U.S. Corn Production

Corn is a crucial component of the U.S. economy, providing economic sustenance to millions of families through its production, marketing and distribution. The United States is the world's largest producer and exporter of corn. In 1996, the U.S. produced 236 million metric tons of corn, accounting for 39.9 percent of the total world production. It exported 46.6 million metric tons in the same year, which formed 70.8 percent of the total world exports.

The last 20 years have witnessed a large increase in U.S. corn production. The area under corn cultivation has grown from 69.9 million acres in 1978 to 73.1 million acres in 1996. The growth in corn production has been even larger, increasing by about 31 percent from its level of 180 million in 1978 to 236 million metric tons in 1996. This expansion in corn supply has been an attempt to meet increasing demands for U.S. corn in the world market which are estimated to have risen from 112.9 to 225.8 million metric tons over the last two decades.

A number of studies have indicated a relationship between the characteristics of the production curves of meat and corn. An analysis by Crum and Stilborn (1997), for example, reported that approximately 80 percent of the total corn produced in the U.S. is used as animal feed. To keep supply commensurate with demand, efforts have been made over the years to increase the output of corn. This has been achieved to a certain degree by expanding the area under corn cultivation and improving the technology used in producing corn. In addition, the recognition of the importance of corn in animal feed has led to endeavors aimed at applying the advances in biotechnology to increase the nutritional value of corn. The result has been the introduction of a large number of new hybrid corn varieties. Assessments of the quality of the new corn varieties have been based primarily on two factors - yield and nutritional value. The performance of new corn varieties in the market place is usually linked to their capability of providing a high nutritional value while at the same time exhibiting high yields. Opaque-2, a hybrid corn developed at Purdue University in the early 1960s, serves to illustrate this fact. Opaque-2 was claimed to have contained more lysine and tryptophan than conventional corn, which enhanced its nutritional capabilities. However, its yield was found to be lower than conventional corn. Moreover, tests conducted at Indiana and Illinois experimental stations indicated that Opaque-2 had lower lysine and tryptophan levels than some other experimental corn varieties, thereby casting doubts on the economic value of Opaque-2, and resulting in its exit from the market.

In recent years, the focus of research has been on the development of new nutritionally value-added grain varieties. In addition, emphasis has been laid on: 1) the identification of systems to quantify specific added values; and 2) the maintenance of corn identity throughout the production and distribution process (Araba, 1997).

High Oil Corn (HOC) and its Evaluation

HOC is one of the recently developed, genetically improved varieties of corn that have gained popularity as a commercial feed ingredient. HOC is produced using the TopCross production system developed by DuPont Agricultural Products. This system involves combining high-yield hybrids with high oil content hybrids. As a result, HOC has an oil concentration of 8 percent, compared to the 4 percent found in conventional corn.

HOC also exhibits a one percent increase in protein content and a 10 percent increase in amino acid digestibility over conventional corn.

A number of reports evaluating the nutritive value of HOC for poultry and swine have surfaced in the literature. Crum and Stilborn (1997) suggests a number of potential advantages of using HOC, some of which are listed below:

1. Reduced feed costs;
2. Possible lower inclusion levels of protein and crystalline amino acid supplementation;
3. Reduced usage of added fats especially those of unknown or poor quality;
4. Consistent source of metabolizable energy (ME) and amino acids:
5. Feed formulation flexibility, and
6. Reduced dust.

The actual operation of George Brauer, a farrow-to-finish producer from Oakford, IL., shows "the high-oil corn ration was cheaper than the typical-corn ration because of the quality of the corn, fat didn't have to be added to the ration, and soybean meal could be reduced. High-oil corn ration can save 30 to 35 cents per bushel in the farrowing ration" (Duxbury-Berg, 1997). According to the estimates from N. Rand et al., Millibar Feed Co., Israel, HOC 's additional value is from \$12 to \$30 per ton--34 to 84 cents per bushel--more than regular corn, depending on the specific formula and the availability and cost of other ingredients (Dudley-Cash, 1997). Some reports also indicate that HOC serves as a more efficacious ingredient in animal feed for broilers and turkeys as compared to conventional corn.

The advantages of using HOC are now being widely recognized among most swine and poultry nutritionists and feed manufacturers. The statistics confirm this: the U.S. Feed Grains Council estimated that roughly one million acres of HOC were planted in 1997, whereas cultivation of HOC in 1993 was virtually non-existent. The numbers indicate a promising future for HOC in the U.S. corn market.

Taiwan and U.S. Corn

Taiwan depends on the U.S. for most of its import corn. Since 1990, Taiwan has imported more than five million metric tons of corn annually from the U.S., roughly 93 percent of the total Taiwanese corn imports. Over the years, Taiwan has gradually become one the U.S. most important corn customers. In 1980, Taiwan was ranked as the tenth largest importer of U.S. corn; by 1996 it was ranked second. The extent of U.S. – Taiwan trade in corn has resulted in a growing awareness among Taiwanese importers of the recent trends and developments in corn production within the U.S. Through the efforts of organizations such as the U.S. Feed Grains Council, attempts have been made to communicate the advances in corn production, storage, testing, and distribution. The benefits of using HOC are, as a result, gradually being recognized in Taiwan. Taiwanese feed manufacturers and growers, however, consider not only the benefits of using HOC in the diet of animals, but also the premium they have to pay. This study assesses these benefits and costs of HOC compared to conventional corn.

II. LITERATURE REVIEW

There are numerous articles discussing the economic impacts of agricultural biotechnology. These impacts include higher end users' demand for livestock products resulting from an enhancement of meat quality, and lower production costs due to technological innovations. These topics have received wide attention.

Kalter and Tauer (1987) and Hueth and Just (1987) have pointed out that changes in agriculture are brought about by new technologies shifting the production function. Lemieux and Wohlgenant (1989) examined the economic impacts of a new growth hormone, porcine somatotropin (PST), on the U.S. pork industry. The results indicate that significant expected benefits exist for both producers and consumers. Chang, Eddeman, and McCarl (1991) conducted research on the effects on welfare from improved rice varieties and water management techniques in the Texas Gulf Coast. They conclude that the adoption of the new productivity-increasing technologies in the U.S. rice production process will provide the producers and consumers net gains if there is no government intervention. Chiou, Chen and Capps (1993) developed a structural quality/quantity model to evaluate the benefits of modified cotton with increased fiber quality. Their analysis shows how improvements in the fiber characteristics of cotton will affect the price of cotton.

Voon and Edwards (1992) attempted to quantify the implicit domestic welfare impacts from modifying Australian wheat to better fit the needs of end-users. They estimate that net profits would increase up to Australia $53 million per year from a one-percentage point increase in the protein content in wheat. McVey et al. (1994) presents a similar study examining the research benefits accruing to producers and end-users from five different soybean modifications. In addition, McVey and Baumel (1997) expanded the extent of the targets to compare the relative economic benefits of eighteen selected supply-enhancing and demand-enhancing modified soybeans. From these studies, it is apparent that there are gains to producers from quality improvements so long as production costs increase by relatively small amounts and yields do not decrease.

The previous studies described the potential benefits from improving certain attributes of raw grain. However, they have a common shortcoming: the products before and after modification in their studies are assumed to be homogeneous. In reality, grain quality is characterized by heterogeneity, and postulating that all grain producers supply the same grain quality is not practical. Quality requirements usually depend on an individual's preferences and purpose for which the corn is to be used. From this follows logically the idea of a differentiated system in which grains with a particular quality are classified separately from other grains with different qualities (McVey, 1996). In McVey's opinion, there are two major points that have to be taken into account while replacing the models described earlier with a differentiated system. First, there is no consistent way to get the substitution effects from producing and processing differentiated quality grains in the previous models. Second, the logistics costs of a quality differentiated system should not be ignored in calculating the value of the commodity in order to arrive at a "credible approximation" of the value. An alternative modeling framework incorporating these features will be used in this study.

Input Characteristic Models

It is hard to gauge the effects of changes in the physical qualities of goods on demand and supply when the assumption of product homogeneity is made. Input characteristic models (ICM) regard an input good simply as a bundle of characteristics and different combinations of those characteristics make the good heterogeneous (Ladd, 1976). This runs counter to traditional economic modeling that takes the product and not its characteristics as the basic element.

Waugh's (1929) pioneer study of the Boston wholesale market collected the wholesale prices and attributes of individual lots of asparagus, cucumbers, and tomatoes and estimated the average prices of the attributes. He concluded many commodities' market prices tend to vary with determined physical characteristics which the consumer identifies with quality. He believed that the statistical analysis could prove that these characteristics and prices had adequate relationships in many commodities. In a study focusing on contemporary improvements in cattle traits, Hazel (1943) suggested that traits be weighted by their economic value. He used the expected increases in profit from each unit of improvement of a trait as the economic value of that trait.

In the late 1970s, input characteristics models capable of deriving the economic values of attributes were conducted on a large scale. Ladd and Martin (1976) developed a consumer model illustrating that an input's purchase price should be equal to a linear combination of its attributes' marginal yield and the attributes' marginal value. Ladd and Suvannunt (1976) applied a similar approach to consumer goods. They showed that a good's price should be set equal to a linear combination of the attributes' yields weighted by their marginal implicit price. They also showed that the consumer demand function consisted of income, product prices and product attribute yields. Based on the results of the Ladd and Suvannunt (1976), Unnevehr (1986) conducted a study to examine the benefits of improving the quality of Southeast Asian rice. She used the implicit prices of rice attributes to evaluate the rice-breeding goals and estimated the returns to research for quality improvement. The results indicated that the physical quality improvement was appreciated and that chemical quality improvements would have potential contributions in the future. The hedonic theory developed by Lancaster (1971) and Rosen (1975) can also be categorized as a branch of ICMs. Mercier et al. (1994) used the hedonic price approach to discuss the relationship between the characteristics of corn and its export price. Uri et al. (1994) adopted the approach to ascertain whether the grain quality factors used by the Federal Grain Inspection Service in assessing the quality grades of wheat exported by the U.S. are the attributes that determine the export price of wheat. Their results suggested that only the test weight and protein content have an apparent relation to the market value. A blending formulation was used by Ladd and Martin (1976) in examining corn-blending problems. Ladd and Gibson (1978) applied the approach to swine production to consider the value of genetic attributes such as average daily weight gain, feed efficiency, and back-fat depth.

Melton, Colette, and Willham (1994) have classified the ICMs as being either(i) neoclassical production models relying on regression estimation of a production function, or (ii) blending models agreeable to analysis by linear or other mathematical programming methods. They thought that neither the neoclassical nor the blending ICMs is fully appropriate when estimating the economic values of genetic attributes. Building on the model established by Melton, Colette, and William (1994), McVey (1996) extended it to explain specifically the logistical aspects of the grain quality issue. The study suggested that the localization of production plays an important role in a quality differentiated distribution system. Elevators and railroads will have a potential impact on the differentiated export market. In this paper, features of the simple blending formulation approach and the differentiated distribution system shall be adopted.

III. MODEL

There are two types of blending problems involving input characteristics. The first type of the blending problem concerns a firm's profit-maximizing mix of outputs to be produced from a given set of inputs given their respective characteristic levels. The second type, which is the more common form, is to estimate the least cost to produce a specified amount of output that is a known combination of characteristics from various input characteristic quantities. For example, the least-cost blending problem for such items as livestock feed rations or sausage are classified into the second type (Melton, Colette, and Willham, 1994). The theoretical framework used in this study will adopt the least-cost blending problem for feed rations.

Least-Cost Blending Problem

The least-cost blending problem makes the following assumptions. A grower purchases blending ingredients at fixed prices. The importer grower is able to obtain both the generic and quality differentiated grain from foreign producers. The attributes of the quality differentiated grain are usually not observable and separable. Soundness attributes for modified grain are assumed to comply with specifications outlined for No. 2 grade grain. Consequently, varieties are only distinguished by their genetic differences (McVey, 1996).

The decision of a grower is either to purchase the quality differentiated grain with a higher premium, or to use the conventional grain in order to minimize the ingredient cost of one unit of output. The least-cost blending problem can be formulated as follows (Silberberg, 1990):

$$\min \underset{1*1}{C} = \boldsymbol{P'X} \tag{1}$$

subject to

$$G(\boldsymbol{X}; \boldsymbol{A}, \boldsymbol{A_0}, \boldsymbol{A_1}, b_0) = 0 \tag{2}$$

where

C = total ingredient cost of one unit of output.

$$\boldsymbol{P} \equiv \begin{bmatrix} p_1 \\ \vdots \\ p_n \end{bmatrix};$$

p_j : price of the j[th] ingredient,

$$\boldsymbol{X} \equiv \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix};$$

x_j : quantity of the j[th] ingredient used per unit of output,

G = a matrix which transform the ingredients to animal feed,

$$\boldsymbol{A} \equiv \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & & \\ a_{m1} & & a_{mn} \end{bmatrix};$$

a_{ij} : level of the i[th] nutrient in one unit of the j[th] purchased input,

$$\boldsymbol{A_0} \equiv \begin{bmatrix} a_{10} \\ \vdots \\ a_{m0} \end{bmatrix};$$

a_{i0} : quantity of the i[th] nutrient required in one unit of output,

$$A_I \equiv \begin{bmatrix} a_{m_0+1,1} \\ \vdots \\ a_{m1} \end{bmatrix};$$

a_{i1} : quantity of the ith nutrient allowed in one unit of output,

b_0 = a given quantity in one unit output,

The objective of the above problem in equation (1) indicates that the total feed cost of one unit of output is the sum of individual ingredient costs. Equation (2) presents the feed output is a function of the quantity of ingredients used per unit of output, quantity of nutrients in each ingredient, and the minimal and maximal requirement of the nutrient.

To solve the miniminzation problem, the following Lagrange function is formed:

$$L(\boldsymbol{X}, \lambda) = \boldsymbol{P'X} - \lambda G(\boldsymbol{X}; \boldsymbol{A}, \boldsymbol{A_I}, \boldsymbol{A_0}; \boldsymbol{b_0}) \tag{3}$$

From the first-order conditions for minimizing L with repect to $\boldsymbol{X}$,

$$L_X = \boldsymbol{P'} - \lambda' G_X(\boldsymbol{X}; \boldsymbol{A}, \boldsymbol{A_I}, \boldsymbol{A_0}; \boldsymbol{b_0}) = 0 \tag{4}$$

$$L_\lambda = G_X(\boldsymbol{X}; \boldsymbol{A}, \boldsymbol{A_I}, \boldsymbol{A_0}; \boldsymbol{b_0}) = 0 \tag{5}$$

where λ is the vector of Lagrange multipliers corresponding to the nutrient minimal and maximal constraints and the quantity of one unit output constraints, respectively. L_X is the whole vector of L_{Xj} 's and L_λ presents the whole vector of $L_{\lambda j}$'s, j = 1,..., n. The solution to the minimization problem can be derived as,

$$\boldsymbol{X}^* = \boldsymbol{X}^*(\boldsymbol{P}, \boldsymbol{A}, \boldsymbol{A_I}, \boldsymbol{A_o}, b_0) \tag{6}$$

The indirect least-cost mixing problems can be expressed as,

$$C^* = \boldsymbol{P'X}^* = P'\boldsymbol{X}^*(\boldsymbol{P}, \boldsymbol{A}, \boldsymbol{A_I}, \boldsymbol{A_0}, b_0) \tag{7}$$

where C^* is the optimal solution of feed cost.

For the linear programming program in this study, the objective and constaints can be stated as follows:

$$\min_{x_j} \quad C = \sum_{j=1} x_j p_j \tag{8}$$

subject to:

$$\sum_j a_{ij} x_j \geq a_{i0} : \quad i = 1,2,\ldots,m_0, m_0+1,\ldots,m \tag{9}$$

$$\sum_j a_{ij} x_j \leq a_{i1} : \quad i = m_0+1,\ldots,m \tag{10}$$

$$\sum_j x_j = b_0 : \quad j = 1,2,\ldots,n-2, n-1, n \tag{11}$$

$$x_j \geq 0 : \quad j = 1,2,\ldots,n-2, n-1, n \tag{12}$$

Equation (9) states that the sum of the quantity of each ingredient's attributes should meet the quantity of nutrient requirement in one unit of output. For the $(m_{0+1})^{th}$ nutrient to the m^{th} nutrient, equation (10) states that the sum of the attributes quantity in ingredients is limited by the allowable quantity of some nutrients. Equation (11) is the constraint that requires the total amount of individual ingredient be a prespecified quantity of feed ration. Equation (12) requires the amount of each ingredient to be nonnegative.

To solve the minimization problem (8) - (12), the solution of $X^* = (x_1^*, \ldots, x_n^*)$ and C* will be obtained as the same form as equations (6) and (7), respectively. To get the added value of quality differentiated grain, we first need to calculate the cost of feed without quality differentiated grain and then the cost of feed with quality differentiated grain. The sum of the cost of generic grain and all other ingredients (excluding the quality differentiated grain) represents the total cost of feed without quality differentiated grain, and is denoted by C_1. Similiarly, the cost of feed with quality differentiated grain can be computed by summing the cost of all ingredients. This cost is called the differentiated feed cost, denoted here by C_2. The added value of the quality differentiated grain per unit, denoted as V_a, can be written by the following equation:

$$V_a = (C_1 - C_2)/x_n = C_s/x_n \tag{13}$$

The added value of the quality differentiated grain is obtained by dividing the cost advantage, represented here by C_s, by the quantity of the quality differentiated grain in the feed.

Value Added Chain

Figure 1 displays diagrammatically the channel between the various parties involved in the value added chain, such as the quality differentiated grain developer, grower, distributor and end-user. The added value from employing quality differentiated grain in animal feed is likely to be split among these agents.

Araba (1997) opines that opportunities for new grain varieties will materialize when they have certain characteristics which include, among others, easily quantifiable benefits to end-users, and an end-user value greater than additional costs incurred by the marketing channel to develop, produce and deliver the product.

In this study, we begin at the second stage of the value added chain described in figure 1, and assume that the steps involved in harvesting and distributing quality undifferentiated and differentiated grain are the following:

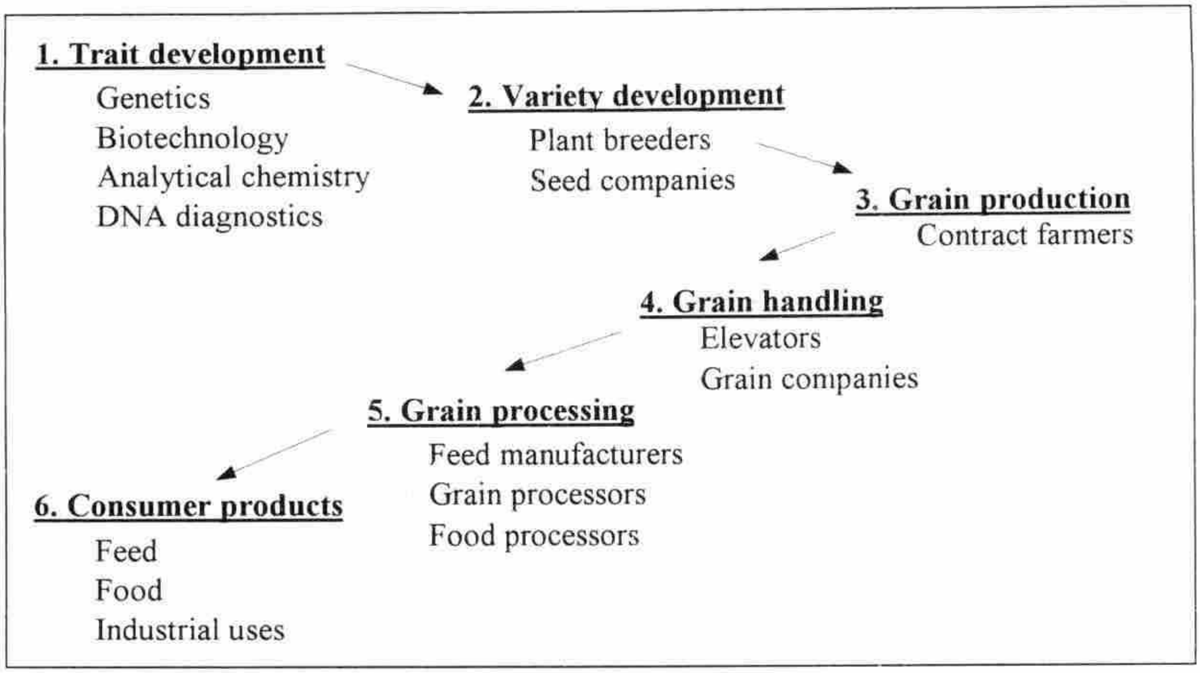

Figure 1: Steps in the development of value-added new grain varieties: Value-added chain. (Araba, 1997)

1. The farmer grows and sells both types of grain to a country elevator,
2. The country elevator receives, tests, stores and ships the grain to a barge terminal, all the while maintaining the identity of each type of grain,
3. The barge terminal receives its corn by rail or truck, maintains the identity of each type of grain, and ships it by barge to New Orleans,
4. A midstreamer transfers the quality differentiated grain from the barge to an ocean vessel,
5. The undifferentiated grain is received at a port of New Orleans elevator and transferred into an ocean vessel,
6. A stevedoring and cargo handling company unloads both types of grain from the ocean vessel at the importer's port and transports the grain to growers, still maintaining separate identities,

The premium (C_R) that importers in Taiwan pay includes the additional production, identity preservation and seed cost and profits. It is calculated by summing the additional produciton costs to the farmer in the U.S. (C_p), additional handling and testing costs at the county elevator (C_e), barge terminal (C_b) and midstreamer (C_m), and the additional seed costs and profits (C_{sd}).

$$C_R = C_p + C_e + C_b + C_m + C_{sd} \tag{14}$$

The end-user's decision of whether to use the quality differentiated grain or not is based on the added value and premium of the quality differentiated grain. If the added value of the grain, V_a, is greater than or equal to C_R, then the grower will import the differeniated quality grain. In contrast, if V_a is less than C_R, there is no advantage to the grower in importing differentiated grain over a conventional grain.

IV. DATA

In order to compare the added value of HOC in Taiwan to the additional costs in transporting HOC from U.S. farms to growers in Taiwan, the relevant data from these two countries have been used. Taiwan's data represent the grain blending information from end-users, whereas the U.S. data address the additional costs of the entire production and distribution process in transporting the grain from U.S. farms to the Taiwan importing port.

Blending Ingredients Data

The representative grower in Taiwan is assumed to have the technology and the requisite facilities to produce the broiler and swine feed. The manufacturer also has the capability of producing feed with or without HOC.

Table 1 presents the attributes intrinsic to conventional corn and to HOC (Araba, 1997). Since HOC has an enlarged kernel, the contents of crude oil, starch, protein and amino acids are all higher for HOC than for conventional corn. This study analyses two varieties of HOC, HOC_a and HOC_b. The nutrient composition of HOC detailed in Table 1 conforms well with those listed in other studies. The Grain Quality Research Progress Report published by the Iowa State University provides information on the average nutrient composition of conventional corn in Iowa. Reports published between 1994 and 1997, for example, indicate that given a moisture content of 15 percent, conventional corn contains an average of 7.7 percent protein and 3.4 percent oil; there are fairly close to the protein and oil composition of conventional corn used in Table 1. The Iowa Gold Catalog (1997), published by the Iowa Department of Agriculture and Land Stewardship, contains data on tests conducted on 19 varieties of HOC. The quantities of the nutritional components of HOC_a in

Table 1: Estimated partial nutrient composition of conventional corn and two high oil corn (HOC) varieties.

Nutrient	Unit	Conventional corn	HOC_a	HOC_b
Moisture	Percent	14.00	14.00	14.00
Crude oil	Percent	3.60	6.50	8.60
Crude protein	Percent	7.90	8.40	8.90
Methionine + cystine	Percent	0.37	0.40	0.42
Methionine	Percent	0.17	0.20	0.21
Lysine	Percent	0.25	0.29	0.33
Arginine	Percent	0.39	0.44	0.48
Poultry ME[1]	Kcal/Kg	3272.40	3436.50	3513.40
Swine ME[1]	Kcal/Kg	3364.20	3519.60	4035.50

[1]ME = metabolizable energy, calculated by Dupont's software, "Estimate 2.01".
Source: Anonymous (1996) as reported by Araba (1997)

Table 1 are approximately equal to the average of the 19 varieties in the Iowa Gold Catalog; among the 19 varieties, HOC_b contains the highest nutritional values. For example, assuming a moisture content of 15 percent, the average protein content of the 19 varieties was 7.6 percent and the average oil content was 6.9 percent. The protein and oil content ranged between 7.0 to 8.5 percent and 6.3 to 8.4 percent, respectively.

In this study, the Brill Feed Formulation System, a linear programming computer package, was used to calculate the least cost feed formulation. At the heart of the Brill program is an optimization model which calculates the least cost mixture of feed ingredients that meet certain nutritional requirements of livestock. However, since the program is not capable of handling certain features peculiar to Taiwanese animal husbandry, certain additional ingredient constraints have been incorporated as well. For example, fish meal is an ingredient rich in amino acids, but has the disadvantage of being relatively expensive.

The Brill program would normally reject the use of fish meal in any cost minimizing ingredient mix that meets the amino acid requirements of the diet. Growers in Taiwan, however, often use fish meal in the diet of broilers because its taste encourages the broilers to consume more feed. The maximum and minimum quantity of specific ingredients, including fish meal, are listed in Table 2. The listed ingredients, prices, and the range of usage of some

Table 2: Nutritional requirements and ingredient prices delivered to Taiwan grower.

Ingredients	Minimum	Maximum	Price[1] (U.S. $/cwt)
Conventional corn	-	-	$ 7.95
Soybean meal (44%)	-	-	11.58
Feed fat	-	-	32.09
Fish meal (broiler only)	3.00	5.00	32.09
Dicalcium phosphate	-	-	18.14
Limestone	-	-	1.87
Salt	-	-	4.20
Lysine	-	-	97.68
Methionine	-	-	202.33
Poultry mineral premix	0.08	0.08	111.63
Poultry vitamin	0.02	0.02	976.77
Swine mineral premix	0.15	0.15	47.44
Swine vitamin	0.10	0.10	260.94

[1] Ingredient price was collected from Taiwan on February, 1998

ingredients were provided by the Taiwan Livestock Research Institute.

The partial nutrient composition of major ingredients listed in Table 3 are based on data in the Nutrient Requirements of Poultry (1994) and Nutrient Requirements of Swine (1988) published by the National Research Council.

Table 3: Nutrient composition of feedstuffs used in poultry and swine diets.

Nutrient	Unit	SBM[1] (44%)	Salt	Fish meal (65%)	Lime-stone	Dical. phos.[2]	Methio-nine	Lysine	Feed fat
Dry matter	Percent	89.00	100	92.00	95	94	98.00	97.00	96
Crude protein	Percent	44.00	-	64.20	-	-	58.69[3]	119.75[3]	-
Methionine + cystine	Percent	1.28	-	2.60	-	-	96.50	-	-
Methionine	Percent	0.62	-	1.95	-	-	96.50	-	-
Lysine	Percent	2.69	-	5.07	-	-	-	78.00	-
Calcium	Percent	0.29	-	3.73	38	22	-	-	-
Nonphytate phosphorus	Percent	0.27	-	-	-	18	-	-	-
Sodium	Percent	0.01	39	0.65	-	-	-	-	-
Arginine	Percent	3.14	-	3.81	-	-	-	-	-
Poultry ME	Kcal/Kg	2230	-	2580	-	-	3680	4600	8100
Swine ME	Kcal/Kg	3392	-	-	-	-	3680	4600	7897
Chlorine	Percent	-	61	-	-	-	-	-	-

[1] Soybean meal
[2] Dicalcium phosphorus
[3] Crude protein equivalent (g/100g) of amino acid
Source: Nutrient requirements of poultry, ninth revised edition, 1994
Nutrient requirements of swine, ninth revised edition, 1988

Table 4 indicates the nutrient constraints for broiler and swine diets. The broiler's life cycle has been divided into two stages, starter (0-4 weeks) and finisher (5-7 weeks). Broiler starters need richer food than the finishers because broilers consume less food in the early stages of their development. Swine are classified by body-weight and are divided between swine weighting 6-10, 11-20, 21-60 and 61-100 kilograms. In this study, swine with body weight 1-5 kilograms were ignored because they consume primarily milk during this stage of their development. The nutrient requirements, including that of vitamins and minerals, used in this study are based on the amounts prescribed by the Taiwan Provincial Department of Agriculture and Forestry. Using the data in Tables 1 to 4, the Brill model identifies the ingredient mix providing the highest nutritional value for the lowest possible costs to the grower. These results were then used to obtain the added value of HOC.

HOC Harvest and Distribution System Data

This subsection provides a detailed account of the entire process involved in transporting corn from the Iowa to Taiwan. Iowa is the largest corn producing state in the United States, and therefore this study assumes that the representative HOC farmer is located there. Furthermore, it is assumed that the farmer grows HOC and sells it to an elevator situated in Farnhamville, a city in Calhoun County. The elevator pays a premium to the farmer and then stores the HOC separate from the conventional corn to preserve its identity. Private industry data indicate that the premium paid to farmers who agree to grow HOC on their land is 25 to 30 cents per bushel. This care in preserving the identity of HOC entails additional segregation and handling costs; the methodology for calculating these costs is presented in Huburgh *et al*(1994). All estimates of handling costs used in this chapter have

Table 4: Primary nutrient requirements of Taiwan's broiler and swine

		Broiler age			
		0-4 weeks[1]		5-7 weeks[1]	
Nutrient	Unit	Min	Max	Min	Max
Crude protein	Percent	23.00	-	20.00	-
Methionine + cystine	Percent	0.90	-	0.72	-
Methionine	Percent	0.50	-	0.38	-
Lysine	Percent	1.10	-	1.00	-
Calcium	Percent	1.00	1.05	0.90	0.95
Nonphytate phosphorus	Percent	0.45	-	0.40	-
Sodium	Percent	0.18	0.23	0.15	.020
Arginine	Percent	1.25	-	1.10	-
ME	Kcal/Kg	3150	3200	3100	3150

		Swine body weight							
		5-10 kg		10-20 kg		20-60 kg		60-100 kg	
Nutrient	Unit	Min	Max	Min	Max	Min	Max	Min	Max
Crude protein	Percent	20.00	-	18.00	-	15.00	-	13.00	-
Methionine + cystine	Percent	0.78	-	0.69	-	0.51	-	0.42	-
Lysine	Percent	1.30	-	1.15	-	0.85	-	0.70	-
Calcium	Percent	0.90	0.95	0.80	0.85	0.70	0.75	0.60	0.65
Nonphytate phosphorus	Percent	0.55	-	0.35	-	0.35	-	0.25	-
Sodium	Percent	0.10	0.15	0.10	0.15	0.10	0.15	0.10	0.15
Arginine	Percent	0.39	-	0.35	-	0.26	-	0.21	-
ME	Kcal/Kg	3360	3629	3264	3525	3120	3370	3120	3370

Source: Taiwan Provincial Department of Agriculture and Forestry and Taiwan Livestock Research Institute.

been obtained from industry sources that handle HOC. The incremental cost of segregation and handling HOC at the country elevator is estimated to be approximately 5-cents per bushel in April 1998. However, the charges are likely to double during the harvesting period between September and November because, at that time, country elevators give priority to handling conventional corn.

The elevator ships the HOC to a barge terminal at East Clinton, Illinois by train or by truck. We assume that the barge terminal is capable of handling all the grain transported from the elevator at Farnhamville, and is able to ship corn by barge during the period from March 1 - November 30. Inclement weather conditions freeze the Upper Mississippi River during December - February. The barge terminal ships the HOC to New Orleans, Louisiana. Incremental handling costs at the barge terminal are estimated to be 3-cents per bushel in April 1998. However, costs could double during high export periods.

At Louisiana, the corn is conveyed from the barge to an ocean vessel in a midstreamer equipped with specialized weighing, sampling and blending equipment for handling grain. In April 1998, this phase of the distribution process involves additional costs of 3-cents per bushel above the cost of transporting the corn into an ocean vessel by an export terminal. Again, this cost could double during high export periods.

The final stage in transporting corn from the U.S. to Taiwan is its shipment via ocean vessel to Kaohsiung Port, Taiwan; the journey takes roughly three weeks. Table 5 presents, in detail, the cost incurred during February 1998 in unloading, storing and transporting conventional corn to poultry and swine growers in Taiwan. Items 1 to 10 are the costs, including taxes, incurred while transporting the grain from the ocean vessel to warehouses in Taiwan. Item 10 indicates the bonus the carrier pays to the grain purchaser for rapid

Table 5: Corn cost estimate per metric ton, February, 1998 (exclude corn C&F price)

Item	New Taiwan Dollar
1. Exchange fee	4.45
2. Insurance 0.096%	4.70
3. Import duty 0.5%	42.01
4. Business tax	26.99
5. Inspection fee + inspection processing fee	12.16
6. Foreign survey fee	5.85
7. Post and telegraphic transfer fee	0.21
8. Domestic survey fee	4.76
9. Unloading, storage second shift extra fee	236.40
10. Dispatch money	-26.32
11.Delivery from warehouse second shift extra fee	17.40
12. Warehouse rent	25.00
13. Unloading tally fee	6.86
14. Custom declaration fee	0.08
15. Inland transportation	112.90
16. Freight car door scaling fee	0.25
17. Key-in and photocopy fee	0.007
Total gross cost	473.71
Discharge shortage rate	0.36%
Total cost	NT $ 475.42

unloading of the grain from the ocean vessel. Items 11 to 15 represent the costs in moving the grain from the warehouses to producers. The inland transportation costs in this example are based on a distance of approximately 15 miles from the wharf to producers. Items 16 and 17 are miscellaneous costs. The discharge shortage rate is the estimated percentage of grain lost during the process of unloading and conveying the grain from the ocean vessel to the warehouse, which adds to the total cost. It is worth noting that there is no additional cost of handling the differentiated grain in Taiwan. The additional handling costs were either too small or non-existent. Therefore they were ignored by the company that imported HOC (Wu, 1998). A plausible explanation for this is that the storage facilities in Taiwan are relatively small compared to the elevators in the U.S.. For example, the cylindrical grain silos in Kaohsiung Port have two sizes, main grain bins and secondary grain bins. The capacities of these bins are 1,240 and 339 metric tons, respectively. Therefore identity preservation in Taiwan is achieved by committing the entire facility to storing HOC rather than segregating a portion of it for that purpose, which reduces handling costs. Moreover, reduction of conventional corn imports with increasing HOC purchases ensures that additional storage costs are not incurred for building new facilities to store HOC.

V. EMPIRICAL RESULT

Benefit Cost Analysis

The results described in this section are based on the assumption that both HOC_a and HOC_b are available in the market. Research data and commercial experience indicate that HOC is used as a substitute for conventional corn and some or all of the added fat, thereby providing a higher energy diet without increasing supplemental fat. The Taiwan data introduced in Chapter 4 were used to calculate the added value of HOC_a and HOC_b through the Brill Feed Formulation System. The results regarding changes in dietary composition and costs for a broiler starter and finisher as well as for a swine diet are presented in Tables 6 to 11.

Tables 6 and 7 show the least cost rations for broiler starter and finisher diets. Tables 8 to 11 show the least cost rations for swine piglet and grower diets. Tables 6 and 7 clearly indicate that adding HOC to broiler starter and finisher diets reduces the quantities of soybean meal, feed fat, and methionine that are needed. For example, in Table 6, the percentage of soybean meal used in the diet decreases from 39.24 when conventional corn is used (feed 1) to 38.46 in the diet comprising HOC_a (feed 2). When HOC_b is added (feed 3), the percentage of soybean meal in the diet decreases still further to 37.51. Similarly, the percentage of fat in the feed also decreases, from 8.33 in feed 1 to 6.74 and 5.66 in feeds 2 and 3, respectively. It should be noted that conventional corn also was added to feeds 2 and 3, but the Brill program rejected the use of conventional corn in the cost minimizing ingredient mix. This indicates the strong substitutability between HOC and conventional corn. The Tables show that the nutrient composition of feed 2 and feed 3 are the same as that

Table 6: Changes and cost of a starter broiler chicken diet containing different high oil corn (HOC) grains[1].

Partial list of ingredients[2]	Unit	Feed 1 Conventional corn only	Feed 2 Conventional plus HOC_a	Feed 3 Conventional plus HOC_b
Conventional corn	Percent	46.06	***	***
HOC_a	Percent	-	48.42	-
HOC_b	Percent	-	-	50.44
Soybean meal (44%)	Percent	39.24	38.46	37.51
Feed fat	Percent	8.33	6.74	5.66
Methionine	Percent	0.15	0.14	0.13
Calculated analysis:				
Crude protein	Percent	23.00	23.00	23.00
Lysine	Percent	1.33	1.33	1.33
Methionine	Percent	0.53	0.53	0.53
Methionine + cystine	Percent	0.90	0.90	0.90
Metabolizable energy	Kcal/Kg	3150	3150	3150
Feed cost, $/metric ton		$255.22	$246.65	$240.55
Added value, cents/bushel of HOC			49.6	81.4

*** Indicates ingredients rejected by the Brill feed formulation system.

- Indicates ingredients not used in the diet.

[1] Ingredients and prices under commercial Taiwan conditions.

[2] Only ingredients where major changes occurred are listed. Conventional corn, HOC_a, HOC_b were given the same price.

Table 7: Changes and cost of a finisher broiler chicken diet containing different high oil corn (HOC) grains[1].

Partial list of ingredients[2]	Unit	Feed 4 Conventional corn only	Feed 5 Conventional plus HOC_a	Feed 6 Conventional plus HOC_b
Conventional corn	Percent	58.82	***	***
HOC_a	Percent	-	61.82	-
HOC_b	Percent	-	-	64.41
Soybean meal (44%)	Percent	30.23	29.25	28.03
Feed fat	Percent	5.05	3.03	1.65
Methionine	Percent	0.03	0.02	0.01
Calculated analysis:				
Crude protein	Percent	20.00	20.00	20.00
Lysine	Percent	1.12	1.12	1.12
Methionine	Percent	0.38	0.38	0.38
Methionine + cystine	Percent	0.72	0.72	0.72
Metabolizable energy	Kcal/Kg	3100	3100	3100
Feed cost, $/metric ton		$228.14	$217.20	$209.41
Added value, cents/bushel of HOC			49.6	81.4

*** Indicates ingredients rejected by the Brill feed formulation system.

- Indicates ingredients not used in the diet.

[1] Ingredients and prices under commercial Taiwan conditions.

[2] Only ingredients where major changes occurred are listed. Conventional corn, HOC_a, HOC_b were given the same price.

Table 8: Changes and cost of a 6-10 kilograms swine diet containing different high oil corn (HOC) grains[1].

Partial list of ingredients[2]	Unit	Feed 7 Conventional corn only	Feed 8 Conventional plus HOC_a	Feed 9 Conventional plus HOC_b
Conventional corn	Percent	50.99	***	***
HOC_a	Percent	-	53.64	-
HOC_b	Percent	-	-	54.50
Soybean meal (44%)	Percent	43.40	42.55	41.64
Feed fat	Percent	2.16	0.36	***
Lysine	Percent	***	***	***
Calculated analysis:				
Crude protein	Percent	23.00	23.00	23.00
Lysine	Percent	1.30	1.30	1.30
Methionine + cystine	Percent	0.78	0.78	0.78
Metabolizable energy	Kcal/Kg	3360	3360	3612
Feed cost, $/metric ton		$212.07	$202.37	$199.47
Added value, cents/bushel of HOC			50.7	64.7

*** Indicates ingredients rejected by the Brill feed formulation system.

- Indicates ingredients not used in the diet.

[1] Ingredients and prices under commercial Taiwan conditions.

[2] Only ingredients where major changes occurred are listed. Conventional corn, HOC_a, HOC_b were given the same price.

Table 9: Changes and cost of a 11-20 kg swine diet containing different high oil corn (HOC) grains[1].

Partial list of ingredients[2]	Unit	Feed 10 Conventional corn only	Feed 11 Conventional plus HOC_a	Feed 12 Conventional plus HOC_b
Conventional corn	Percent	61.19	***	25.19
HOC_a	Percent	-	62.51	-
HOC_b	Percent	-	-	37.62
Soybean meal (44%)	Percent	35.74	34.37	34.08
Feed fat	Percent	***	***	***
Lysine	Percent	0.03	0.06	0.05
Calculated analysis:				
Crude protein	Percent	20.82	20.44	20.49
Lysine	Percent	1.15	1.15	1.15
Methionine + cystine	Percent	0.69	0.69	0.69
Metabolizable energy	Kcal/Kg	3275	3369	3525
Feed cost, $/metric ton		$192.58	$192.10	$191.84
Added value, cents/bushel of HOC			2.2	5.6

*** Indicates ingredients rejected by the Brill feed formulation system.

- Indicates ingredients not used in the diet.

[1] Ingredients and prices under commercial Taiwan conditions.

[2] Only ingredients where major changes occurred are listed. Conventional corn, HOC_a, HOC_b were given the same price.

Table 10: Changes and cost of a 21-60 kg weight swine diet containing different high oil corn (HOC) grains[1].

Partial list of ingredients[2]	Unit	Feed 13 Conventional corn only	Feed 14 Conventional plus HOC_a	Feed 15 Conventional plus HOC_b
Conventional corn	Percent	77.83	14.91	63.81
HOC_a	Percent	-	63.13	-
HOC_b	Percent	-	-	14.27
Soybean meal (44%)	Percent	19.03	18.82	18.79
Feed fat	Percent	***	***	***
Lysine	Percent	0.16	0.16	0.16
Calculated analysis:				
Crude protein	Percent	15.00	15.00	15.00
Lysine	Percent	0.85	0.85	0.85
Methionine + cystine	Percent	0.54	0.54	0.54
Metabolizable energy	Kcal/Kg	3275	3370	3370
Feed cost, $/metric ton		$183.61	$183.28	$183.38
Added value, cents/bushel of HOC			1.5	4.5

*** Indicates ingredients rejected by the Brill feed formulation system.

- Indicates ingredients not used in the diet.

[1] Ingredients and prices under commercial Taiwan conditions.

[2] Only ingredients where major changes occurred are listed. Conventional corn, HOC_a, HOC_b were given the same price.

Table 11: Changes and cost of a 61-100 kg weight swine diet containing different high oil corn (HOC) grains[1].

Partial list of ingredients[2]	Unit	Feed 16 Conventional corn only	Feed 17 Conventional plus HOC_a	Feed 18 Conventional plus HOC_b
Conventional corn	Percent	83.92	29.56	71.80
HOC_a	Percent	-	54.54	-
HOC_b	Percent	-	-	12.33
Soybean meal (44%)	Percent	13.40	13.21	13.19
Feed fat	Percent	***	***	***
Lysine	Percent	0.15	0.14	0.14
Calculated analysis:				
Crude protein	Percent	13.00	13.00	13.00
Lysine	Percent	0.70	0.70	0.70
Methionine + cystine	Percent	0.50	0.50	0.50
Metabolizable energy	Kcal/Kg	3287	3370	3370
Feed cost, $/metric ton		$178.11	$177.83	$177.91
Added value, cents/bushel of HOC			1.5	4.5

*** Indicates ingredients rejected by the Brill feed formulation system.

- Indicates ingredients not used in the diet.

[1] Ingredients and prices under commercial Taiwan conditions.

[2] Only ingredients where major changes occurred are listed. Conventional corn, HOC_a, HOC_b were given the same price.

of feed 1, from which we can conclude that reducing other ingredients does not affect the nutritional value of the diet. The inclusion of HOC also decreases broiler feed cost by replacing more expensive sources of energy and protein. Moreover, the risk involved in purchasing unknown quality added fats is practically eliminated, which ensures a consistent and high quality diet. Tables 8 to 11 summarize the results of the Brill output of swine. Table 8 shows that in the diet of swine weighting 6-10 kilograms, the program rejected the use of conventional corn when HOC was added. Tables 10 and 11 indicate that for all swine with body weights above 21 kilograms, the Brill program included both conventional corn and HOC in the optimal ingredient mix, while Table 9 shows that for some weights between 11 and 20 kilograms, adding HOC_a removed the need for any conventional corn; however HOC_b had to be supplemented by conventional corn. The main reason for these results is the constraints placed on the maximum metabolizable energy (see Table 4). Excess fat in the diet of growing swine reduces pork quality, and this limits the amounts of HOC that can be used in the diets of 21-100 kilograms swine.

From the savings in total feed cost, the added values of HOC_a and HOC_b in broiler diets were estimated to be 49.6 cents and 81.4 cents per bushel, respectively, above conventional corn. The feed cost savings and added values of HOC_a and HOC_b in 6-10 kilograms swine diets are significantly higher than those in 11-100 kilograms swine. The added values of HOC_a and HOC_b used in 6-10 kilograms swine diet were 50.7 cents and 64.7 cents per bushel, respectively. However, for 11-100 kilograms swine diet diets, the added value of HOC_a was at most 2.2 cents and that of HOC_b was not higher than 5.6 cents per bushel. The value of adding HOC to the 11-100 kilograms swine diet is therefore relatively small compared to adding it to the broiler and 6-10 kilograms swine diets. In Tables 10 and

11, the added value of HOC_a in feeds 15 and 18 is higher than the added value of HOC_b in feeds 14 and 17 even though the feed cost savings from using HOC_b is less than that from using HOC_a. This can be explained on the basis of that the calculation of added value is dependent on the percentage of HOC used. As is evident from Tables 10 and 11, the percentage of HOC_b used is much lower than the percentage use of HOC_b. Figure 2 shows the relative percentage of HOC_a, HOC_b and conventional corn for different swine body

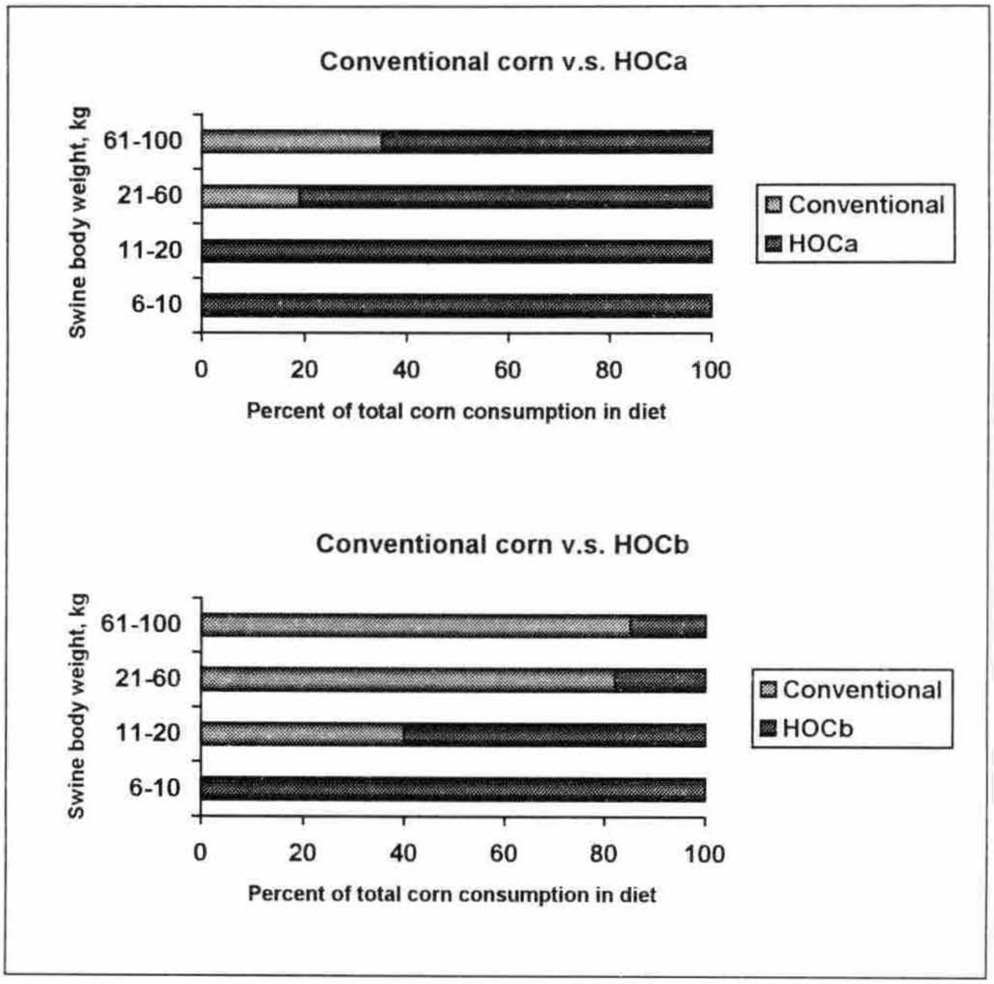

Figure 2: Percentage of HOCa, HOCb and conventional corn used in swine diets

weight. The percentage of HOC_b used in different body weight swine drops relative significantly than HOC_a did.

The added values of both HOC_a and HOC_b used in broiler and swine diets are summarized in Table 12. The weighted average in the Table is the average of the added value of using HOC in each stage weighted by fraction of the total feed intake during the entire life cycle of the animal that is consumed in each stage.

Table 12: Added value of HOC_a and HOC_b in broiler and swine rations, cents/bushel.

	Broiler			Swine				
	Starter	Finisher	Weighted average	6-10 kg	11-20 kg	21-60 kg	61-100 kg	Weighted average
HOC_a	49.6	49.6	49.6	50.7	2.2	1.5	1.5	2.9
HOC_b	81.4	81.4	81.4	64.7	5.6	4.5	4.5	6.2
Feed intake, kg/animal	1.5	2.8	--	7.5	20.0	110.8	138.7	--

Table 13 indicates that the additional production and identity preserved costs were found to range between 36 and 52 cents per bushel. The additional production cost, additional handling costs incurred by elevators, barge terminals, midstreamer terminals and are all included in the additional costs. These costs exclude additional seed costs and profits. In April 1998, the additional production and handling costs are estimated to be 36 cents per bushel. These costs can increase to as high as 52 cents per bushel during periods of harvest and high exports.

According to data obtained from industry sources, the official premium in April 1998 charged to importers of HOC in Taiwan was 50.7 cents per bushel. This implies that the

Table 13: Additional cost to get HOC from Iowa to Taiwan over conventional corn in cents per bushel in 1998

Variables	Difference*
Premium to Iowa farmer	25 – 30
Elevator handling	5 - 10
Barge terminal handling	3 - 6
Midstreamer transfer from barge to ocean vehicle	3 - 6
Total	36 - 52

*Assumes the same transport costs for both types of corn

additional seed costs and profits were 14.7 cents per bushel. The differences between the added value of using HOC and the premium are summarized in Table 14. As Table 14 indicates, the added value of introducing HOC_a in broiler diets is marginally lower than the premium. For 6-10 kilograms swine, the added value and the premium were found to be equal, whereas for the 11-100 kilograms swine, the additional costs involved in using HOC_a far exceed its added value. For HOC_b, it is evident that the benefits of adding it to both

Table 14: Comparison of growers profits form using HOC in broiler and swine rations in Taiwan using April, 1998 prices and charges in cents per bushel

	Broiler		Swine			
	Starter	Finisher	6-10 kg	11-20 kg	21-60 kg	61-100 kg
HOC_a	-1.1	-1.1	0.0	-48.5	-49.2	-49.2
HOC_b	30.7	30.7	14.0	-45.1	-46.2	-46.2

broiler and 6-10 kilogram swine diets are greater than the premium. This is not true in the case of 11-100 kilograms swine diets. The characteristic of HOC which primarily distinguishes it from conventional corn is its higher fat content. Since growing swine requires low amounts of fat, the benefits of using HOC in their diets are not high enough to exceed the premium. These results indicate that, in general, the added value of HOC tends to be greater when used in the diets for the various stages of the life cycle of animal that require supplemental fat to meet their energy requirements.

The findings in Table 14 indicate that it is not always profitable to import HOC_a. However, there are other factors that affect the livestock grower's decision. For example, in Taiwan, most of the animals are fed high-energy diets that are commonly supplemented with at least one source of fat. Using HOC can reduce many of the difficulties and risks experienced by the feed manufacturers and growers in mixing the added fat. Moreover, using HOC can help the growers protect the animals from heat stress. The warm and humid climatic conditions in Taiwan are not always conducive to animal husbandry. The optimal growth and development of animals require the presence of certain ranges in temperature. The ideal temperature range for raising swine, for example, is between 20^0 C and 24^0 C. At high temperatures, animals suffer from heat stress which is characterized by reduced feed intake, emaciation and for layers, lowered egg production. Severely affected animals quit eating altogether, and consequently die. Heat stress is a problem encountered often in Taiwan, where temperatures greater than 30^0 C are not uncommon. In these circumstances, adding HOC to animal diet has certain advantages. First, the reduced feed intakes by animals make it imperative that the meet the metabolizable energy requirements. HOC is ideal for this purpose. Second, the addition of HOC reduces the amount of supplemental fat required in the diet. This decreases the difficulties and costs involved in storing the supplemental fat as extreme caution has to be taken to maintain the quality of fat in hot and moist conditions. These non-measurable considerations play an important role in the decision to import HOC. This is evident from the fact that the HOC imported by Taiwan at present has attributes similar to HOC_a.

The measurable benefits of using HOC_a can be increased if the additional costs are reduced. The livestock growers in Taiwan are often able to lower the premium through negotiations to as low as 40.6 cents per bushel. This could result in the difference between the added value and premium of HOC_a increasing to 9 cents per bushel for broiler diets and to 10.1 cents per bushel for 6-10 kilograms swine diets.

As shown in Table 14, the added value of using HOC_b exceeds the premium by 30.7 cents per bushel for broilers and by 14 cents per bushel for 6-10 kilograms swine. Given that the measurable benefits of using HOC_b are greater than those of using HOC_a, and that the non-measurable benefits are the same for both, it is apparent that both Taiwanese importers and U.S. grain suppliers would find it advantageous to trade HOC_b rather than HOC_a.

Assume that the farmer premium and additional handling costs increase from 36 to 52 cents per bushel as shown in Table 13. In addition, assume that the 14.7 cents per bushel for additional seed cost and profits are added to the 52 cents. Under these assumptions, Table 15 presents the grower profits from using HOC. Table 15 shows that the added value of using HOC_a is far lower than the premium; this reduces the attractiveness of HOC_a, even in the presence of non-measurable benefits. Importing HOC_b with increased handling costs reduces the profitability when used in the broiler feed and results in a loss to the Taiwan grower when used in the feed of 6-10 kilograms swine.

Table 15: Comparison of growers profits from using HOC in broiler and swine rations in Taiwan using the higher additional costs in Table 13 in cents per bushel

	Broiler		Swine			
	Starter	Finisher	6-10 kg	11-20 kg	21-60 kg	61-100 kg
HOC_a	-17.1	-17.1	-16.0	-64.5	-65.2	-65.2
HOC_b	14.7	14.7	-2.0	-61.1	-65.2	-65.2

Table 16 provides estimates of the quantities of HOC_b that would be used in broiler and swine diets if it were imported by Taiwan. Of the 177.62 million bushels of corn added to the feed of broilers and swine (having body weights of 6 - 100 kilograms) in Taiwan, HOC_b would account for only 35.74 million bushels, approximately 20 percent of total corn usage. In the HOC_b usage, 8 percent is used in the diets of 6-10 kilograms swine and other 92 percent goes to broiler diets. Under the higher handling costs listed in Table 15, all imported HOC_b would be used in broiler diets.

Table 17 analyzes the effects of using HOC_b on feed costs and on corn, soybean, feed fat and methionine usage in broiler and 6-10 kilograms swine diets. The Table shows that the HOC reduces the weighted average feed cost by $16.90 per ton. Total corn usage increases by 3.0 millions of bushels but the total usage of soybean, feed fat and methionine decreases by 1.6 millions of bushels, 51.8 thousand tons and 0.30 thousand tons, respectively. Since HOC_b is relatively cheaper than soybean meal, feed fat and methionine, the risks experienced by growers due to changes in the prices of ingredients are mitigated. However, the results in Table 15 are based on the unlikely assumption that soybean, feed fat and methionine prices do not change in response to the loss of market share.

Table 16: Estimated consumption of corn by broilers and swine

	Broilers		Swine				
	0-4 week	5-7 week	5-10 kg	10-20 kg	20-60 kg	60-100 kg	Total
Number of animals in Taiwan (millions)[1]	324.1	324.1	16.8	16.8	16.8	16.8	
Feed consumption in kg/animal[2]	1.52	2.83	7.50	20.00	110.77	138.67	
Percent in ration							
Conventional corn	-	-	-	61.79	77.83	83.50	
HOC_b	50.44	64.41	54.50	-		-	
Total bushels of corn consumed (millions)							177.62
Conventional corn	-	-	-	8.11	57.10	76.68	141.88
HOC_b	9.78	23.25	2.71	-	-	-	35.74
Percent of HOC_b in the total corn market of broiler and swine diets							20.12

[1] Taiwan Provincial Department of Agriculture and Forestry, 1996
[2] Taiwan Livestock Research Institute

Table 17: Impact of HOC_b on feed costs and corn, soybean, feed fat, usage in swine and broiler feeds.

Variable	Species	Type of corn in the ration: Conventional only	Type of corn in the ration: Conventional plus modified	Net change	Percent change
Feed cost per ton	Broilers (0-4 weeks)	$255.2	$240.5	-$14.7	-5.7
	Broilers (5-7 weeks)	228.1	209.4	-18.7	-8.2
	Swine (6-10 kgs)	212.1	199.5	-12.6	-5.9
	Average	$235.5	$218.6	-$16.9	-7.2
Corn usage in millions of bushels	Broilers (0-4 weeks)	8.9	9.8	0.8	9.5
	Broilers (5-7 weeks)	21.2	23.3	2.0	9.5
	Swine (6-10 kgs)	2.5	2.7	0.2	6.9
	Total	32.7	35.7	3.0	9.3
Soybean usage in millions of bushels	Broilers (0-4 weeks)	9.9	9.5	-0.4	-4.4
	Broilers (5-7 weeks)	14.2	13.2	-1.0	-7.3
	Swine (6-10 kgs)	2.8	2.7	-0.1	-4.0
	Total	26.9	25.3	-1.6	-5.9
Feed fat usage in thousands of tons	Broilers (0-4 weeks)	45.2	30.7	-14.4	-32.0
	Broilers (5-7 weeks)	51.1	16.7	-34.4	-67.3
	Swine (6-10 kgs)	3.0	0.0	-3.0	-100.0
	Total	99.3	47.5	-51.8	-52.2
Methionine usage in thousands of tons	Broilers (0-4 weeks)	0.81	0.73	-0.08	-10.0
	Broilers (5-7 weeks)	0.33	0.13	-0.20	-60.6
	Swine (6-10 kgs)	0.04	0.03	-0.02	-40.6
	Total	1.19	0.89	-0.30	-25.3

The empirical results described in this chapter illustrate the advantages of importing HOC by Taiwan. HOC_b provides greater measurable benefits than HOC_a. To make the latter more cost effective for Taiwanese importers, it would be necessary for U.S. grain companies to reduce the premium charged to importers of HOC_a. This can be achieved in two ways: either by reducing the additional handling costs or by decreasing the profits of U.S. grain suppliers.

VI. CONCLUSION

The main purpose of this study was to evaluate the benefits and costs involved in switching from conventional corn to high oil corn by Taiwanese importers. The methodology used to undertake this evaluation was as follows:

1. Estimating the potential added value of HOC in animal diets using a linear programming model.
2. Obtaining the additional costs of segregating and shipping HOC to Taiwan.
3. Comparing the added value of HOC to the additional costs of importing HOC.

The analysis reflects to a large extent the economic impacts of recent improvements in biotechnology. Two types of HOC were analyzed, HOC_a and HOC_b.

This analysis produced a number of results which indicate the potential uses of imported HOC from the U.S.. It was found that adding HOC to animal feed reduces the amount of certain other ingredients that have to be used, thereby lowering the cost to growers without altering the nutrient content of the feed. For HOC_b, the total usage of soybean, feed fat and methionine in broiler and 6-10 kilograms swine diets decreased by 1.6 million bushels, 51.8 thousand tons and 0.3 thousand tons, respectively. This reduction in added feed supplements also eliminates to a large extent a number of risks the grower faces such as the poor quality of added fats and the lack of guarantee of a consistent diet.

The added value of HOC used in broiler and 6-10 kilograms swine diets ranged between 49.6 cents and 50.7 cents per bushel for HOC_a and 64.7 cents and 81.4 cents per bushel for HOC_b. In comparison, the premium was found to be 50.7 cents, clearly indicating that the benefits of importing HOC_b for use in the feed of these animals are greater than the costs. HOC_b is therefore more profitable for suppliers and end-users than HOC_a. For 11-100 kilograms swine diets, however, the added value of HOC_a was 2.2 cents per bushel and that of HOC_b was 5.6 cents per bushel at most, both of which are less than the premium of HOC.

Given a premium of 50.7 cents per bushel, there are five conclusions that emerge from these results. First, importing HOC_b is profitable when it is intended to be used in the feed of broilers and 6-10 kilograms swine, whereas the cost of importing HOC_a was greater than the measurable benefits when used in the diet of broilers and swine. Second, it seems that the added value of HOC is greater when included in the feed of animals that require a higher fat content in their diets. Third, given that there are no measurable benefits in importing HOC_a, the fact that Taiwanese importers do actually import HOC_a can be explained only on the basis of risk management. Fourth, since HOC_b has the same non-measurable benefits as HOC_a but higher measurable benefits, switching from HOC_a to HOC_b would be beneficial for Taiwan. The first conclusion has to be modified slightly if we assume different values of the premium. Specifically, when the additional handling costs were increased to 52 cents per bushel, importing HOC_b could no longer be profitable when used in the diet of 6-10 kilograms swine. Finally, at a premium of 50.7 cents per bushel, only 8 percent of total HOC_b imported would be used to feed swine and 92 percent be used to broilers diets. From conclusion four, all imported HOC_b will be used to feed broilers at the high handling costs condition. This indicates that the basic purpose for importing HOC_b into Taiwan is largely for use in broiler diets.

VII. FURTHER RESEARCH

This chapter takes a brief look at how the model employed in this study can be extended in future research. Chapter 3 enunciated the basic linear programming (LP) model used to estimate the potential value of HOC. The model assumes fixed prices for all ingredients. This assumption is not likely to hold under all conditions. To introduce more realism, alternative approaches such as the use of quadratic programming or stochastic modeling should be considered.

Other areas for potential future research include incorporating the effects of cross price elasticities in demand and supply, and of variations in exchange rates. The former is an important extension. As described in earlier chapters, adding HOC to animal feed reduces the quantities of other ingredients such as soybean meal, feed fat and methionine that need to be used to maintain the nutritional value of the diet. However, the decision to substitute other ingredients with HOC depends to a large extent on their relative prices. Estimation of cross price elasticities is therefore essential to analyze the effect of price changes on the grower's decision to import HOC.

Another simplifying assumption in this study is that of the existence of a single path of distribution. In reality, the distribution system involves a large number of different transportation routes and a variety of alternative modes of transportation. A broader formulation of the model taking this into account presents the grain suppliers with more choices and would clearly reduce, or at worst keep constant, the cost of transporting HOC found in this study. Some specific examples of alterations made to the distribution system which would reduce transportation costs are:

1. The use of shuttle trains. Shuttle trains are scheduled trains connecting specific origins and destinations. This facilitates efficient low cost grain shipments to alternative ports and routes.
2. Using large barges from St. Louis to New Orleans, Louisiana. Since the depth of river channel is only nine feet north of St. Louis, the size of barges used in Iowa is relatively smaller than south of St. Louis. The 12 foot channel south of St. Louis permits the use of larger barges in St. Louis and this would lower the distribution costs.
3. By- passing country elevators. Farms located in eastern and east central Iowa may find it more economical to transport the grain in trucks directly from farms to the Mississippi River terminal rather than through the county elevators. This eliminates the county elevator costs as well as the trucking cost from the farm to the elevator.
4. Increasing the volume of HOC exports so that exporters can negotiate lower costs for handling and transporting the grain.

Finally, this study assumed that the exchange rate is constant. The New Taiwan Dollar (NT $) has, however, depreciated from 27.5 NT $/U.S. $ to 34.5 NT $/U.S. $ during October 1997 and June 1998. Exchange rate fluctuations have a number of implications for import and export decisions. For example, a depreciation of the NT $ by 18 percent between October 1997 and February 1998 served to negate the fall in C&F (cost and freight) price of conventional corn. Gauging the effects of variations in the exchange rates on the profitability of importing HOC would be a fruitful area for further research.

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